Regional Intercomparison of Dobson Spectrophotometers for Asia

Aerological Observatory of the Japan Meteorological Agency in Tsukuba, Japan

7-25 March 2016

(DIC-T2016)

Final Report

Prepared by

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1. Purpose of the Intercomparison

The Japan Meteorological Agency (JMA) sponsored the WMO/GAW Regional Intercomparison of Dobson Spectrophotometers for Asia, 2016 (DIC-T2016), as an activity of WMO Regional Dobson Calibration Center for Asia (RDCC-A) operated by the JMA. This campaign was supported by the budget of "General Trust Fund for Financing Activities on Research and systematic Observations Relevant to the Vienna Convention". Additional support in the form of expert personnel was provided by the U.S. National Oceanic and Atmospheric Administration (NOAA). The main purpose of DIC-T2016 was to support the maintenance and to improve the function of the ground-based total ozone monitoring network in the RA-II Region. The long term quality controlled total ozone data obtained from Dobson observations within the framework of the WMO Global Atmosphere Watch (WMO/GAW) are essential to the assessment of the state of the ozone layer by accurate and reliable ozone data.

The DIC-T2016 consisted of the Intercomparison (IC) of Dobson instruments with the Regional Standard Dobson Instrument D116, maintained by the JMA. Instruments and personnel from China (Xianghe : D075), Pakistan (Quetta : D100), and Thailand (Bangkok : D090) attended the IC. Dobson instrument D075 belonging to China was calibrated in 2011. D090 from Thailand and D100 from Pakistan were last calibrated in 2006. The Iranian Dobson (Teheran: D109) was out of order and therefore unable to attend the IC. The Philippines opted to calibrate their instrument (D052) against the region V standard (D105) at an IC to be held in Australia in 2017. The Indian Dobson (D036) and the Chinese Dobson (Kunming: D003) were also unable to participate due to delays in transport procedures of the instruments.

The main tasks of the mission were:

- The technical inspection and adjustment of the instruments
- Comparison of the Dobson spectrophotometers against the Regional Standard Dobson (D116), by simultaneous side-by-side observations on the sun to determine the existing state of calibration.
- Determination of new calibration constants for each Dobson spectrophotometer, as needed.
- To instruct participants in the proper operation of the Dobson spectrophotometer and processing observations at their home stations, and sharing knowledge concerning the management of the ozone observing program.

2. Operation

All Intercomparisons were held on the roof platform of the Aerological Observatory at Tsukuba. Technical work on instruments and processing of test data were performed in the laboratory facility of the same building.

The DIC-T2016 technical operation was controlled by a scientific committee consisting of the following experts:

Mr. Glen McConville

Technical Director of DIC-T2016 from the World Calibration Center, NOAA-GMD, Boulder, Colorado.

Mr. Ryoichi Kajihara

Technical Advisor of DIC-T2016, retired ozone coordinator in JMA.

Mr. Keisuke Ueno

Technical Staff of DIC-T2016 from Regional Dobson Calibration Centre for Asia (RDCC-A), JMA, Tsukuba, Japan.

Mr. Satoru Shimizu

Technical Staff of DIC-T2016 from Regional Dobson Calibration Centre for Asia (RDCC-A), JMA, Tsukuba, Japan.

The following national Dobson spectrophotometers and their operators participated in the DIC-T2016:

Instrument	Operator	Station/Section
D075	Dr. Chao LING & Ms. Yanliang ZHAO	Xianghe / Chinese Academy of Science
D090	Ms. Duanchai SEESAMUT	Bangkok/ Thai Meteorological Department
D100	Mr. Rasheed Abdul SYED	Quetta/ Pakistan Meteorological Department

All work and intercomparisons were mostly scheduled according to weather conditions. However the weather conditions during this event weren't particularly favorable and fewer IC were performed that we hoped. Also, Dobson D090 was in need of extensive maintenance, and the Chinese participants and Dobson D100 were delayed in arriving which also caused us to alter our agenda.

The main steps of the event were as follows:

- Instrument D090 was unpacked and inspected on March 7th. The instrument was both packed well and clean. However, the micro-ammeter was noisy, the selector switches had little effect on the signal level, and it exhibited poor symmetry, PMT placement tests. Additionally the mercury lamp tests were difficult to repeat. We concluded that it could not participate in an IC is such conditions and the cause was investigated. We first discovered that the cobalt filter was extremely degraded and needed replacing. The cobalt filter was replaced with a new one and results of the mercury and standard lamps tests to shift to those in the previous calibration in 2006, but did not fix the overall problem with the mercury tests. The old cobalt filter was placed back in the instrument, but this didn't return the instrument to its condition before the replacement of the cobalt filter. Further investigation showed that the high voltage selector switch had limited range and an electrical potentiometer had completely failed. This caused the operators to use the micro-ammeter shunt to adjust the signal and the PMT was being saturated –hence the poor mercury tests. When the mercury lamp was attenuated by other means, the tests were both normal and repeatable. And a two-lamp test was performed on D090.

- Dobson D100 was released from customs and arrived on March 9th. Standard and mercury lamp tests were normal, but an inspection of the machine's interior should a significant amount of dust on all the optical surfaces. And the standard lamp power supply as in need of replacement.

- Additional standard lamps were built for instruments D75 and D90 on March 11th.

- The participants from China arrived on the 14th and their instrument (D075) was unpacked and inspected. It was both clean and well packed, and the results of initial lamp tests appeared normal.

- An initial intercomparison was performed between the regional standard Dobson (D116), D075, D100, and D090 in the morning on March 15th.

- The power supplies and attenuator switches within D090 were replaced and a two-lamp test was performed on D100 on March 15th.

- A two-lamp test was performed on D075 and D100, and the optics was cleaned on all Dobson instruments.

- IC was performed in the afternoon on March 17. All three instruments performed reasonably well. The calibrations of D075 and D100 were deemed finished, but D090 still showed to be required additional work on the high voltage attenuator.

- Optics of D090 was cleaned on March 18. And additional work was performed on the electronics of D090, both shutter levers were replaced, and Q1 and Q2 levers reset.

- Due to poor weather conditions, the next several days until March 21 were dedicated to instrument maintenance. Two-lamp tests and new wedge calibrations were performed on all three instruments.

- Two intercomparisons were performed on the morning and afternoon on March 22. All three instruments performed reasonably well. The calibrations of D075 and D100 were deemed finished, but D090 showed some mu dependence and an additional intercomparison was scheduled for the following day.

- The weather wasn't favorable for intercomparisons on March 23rd and the forecast for the rest of the week was poor. We accepted the results of D090 from the day before with the caveat that observations should not be made beyond the range of mu = 2.5, and it's recommended that M1 be replaced during its next calibration.

- Results of the intercomparisons and recommendations were discussed with the participants, and lamp tests were performed.

4.Conclusion

All instruments left the IC with proper calibration constants and in correct operating order.

5. Recommendations

Due to a slight mu dependence in the AD direct sun measurements, it's recommended that instrument D090 should not make observations at mu greater than 2.5. Since it is operated in

Bangkok Thailand at latitude of approximately thirteen degrees north, this should not appreciably impinge on their current observation schedule.

It's recommended that the standard lamp power supply for D100 be replaced. A new one will be sent directly from the world calibration center in Boulder, Colorado.

Calibrations on these instruments should be performed on a more frequent schedule. I would suggest every five years at the most. The effects of allowing ten years between calibrations were evident on all instruments, and significant personnel changes had taken place at the stations.

It's also recommended that standard operational procedures of Dobson instruments written in GAW report No. 183 should be followed at the each observatory to ensure continuous observation data quality.

It's suggested that data from these stations between the 2006 and the 2016 intercomparisons be reassessed and appropriate drift corrections applied.

The director acknowledges the indispensable wisdom of the technical assistant Mr. Kajihara, and assistance from the staff at the JMA Aerological Observatory.

The director was impressed and appreciative of the resources dedicated to this intercomparison from the WMO/GAW, and the JMA. The needed tests and maintenance could not have been performed without their personnel, material and financial support.

Instrument: D075

Station: Xianghe, China

Report on re-calibration and maintenance performed 2016

Original Calibration Data:

N-tables (September 2011) from intercomparison with D116 in Tsukuba Japan.
Standard lamp values for 075J1, 075Q3, 075J2 and 075Q2. 075Q2 was only used until its failure in November 2011.

History:

D075 is routinely operated the station in Xianghe, China using calibration constants from DIC-T 2011.
Due to failure of the standard lamp power supply, no standard tests were performed after April 2013.
Mercury lamp tests were not preformed since July 2013.

Initial Calibration Results: March 15, 2016 against D116:

d_Na: +0.92 d_Nc: +0.65 d_Nd: +0.53 d_Nad: +0.39

The d_Nad difference implies an average **error of 0.41%** mu=1.3 to 2.5, Total Ozone = 400 Dobson units

Work Performed:

- Symmetry test
- Two lamp tests prior to and after optical cleaning
- Optical cleaning
- Desiccant drying system was replaced
- Standard lamp was replaced from 075Q2 to 075Q4
- The sun director prism was inverted due to small scratches on one surface
- New standard lamp values were assigned to 075J1, 075J2 and 075Q3

Final intercomparison:

A new G-table was established from a two lamp test and corrections applied from IC performed on March 17th.

d_Na: -17.00 **d_Nc: -14.14** **d_Nd:- 13.30**The results showed an average **+0.06% TCO difference** from the standard at **320 DU from mu = 1.25 to 2.5**

Comments:

There was a large shift in the wedge calibration, but the overall shape of the edge remained the same. Most of the error in the final intercomparison appears to come from the A wavelength pair at higher mu levels. This likely could have been improved by adjustment of M2. However there was a delay in the arrival of the Chinese representatives and afterward insufficient time and sun to fully investigate this issue.

Recommendations:

- Perform and document mercury and standard lamp tests at least monthly. Standard lamp tests are extremely important for data quality.
- Use higher PMT voltage during observations. A one degree change in the R-dial should result in a +/- 5 micro-amp change of the galvanometer.
- Check desiccant air flows more often. Once a month during lamp tests at a minimum. High humidity will affect the instruments calibration.
- Avoid observations beyond mu = 2.5.
- Past R to N table is no longer valid. Begin using new table.
- Operators should note that Q2 settings are not nearly as critical as Q1.

Instrument: D090

Station: Bangkok, Thailand

Report on re-calibration and maintenance performed March 2016

Original Calibration Data:

N-tables (March, 2006) from intercomparison with D116 in Tsukuba Japan.

History:

D090 is routinely operated at the Bangkok station using calibration constants first defined in DIC-T 1996 and adjusted in DIC-T 2006.

The total ozone data are regularly reported to the WOUDC.

Mercury and standard lamp tests are performed monthly and properly recorded. The mercury tests were mostly within limits between 2006 and 2016 and seldom drifted more than 0.5 degrees.

The standard lamp tests showed a reversing trend beginning in 2011, which I attribute to the declining state of the cobalt filter. However the relationship between the A and D remained mostly unchanged and the overall relationship between ozone values retrieved by 90 and OMI satellite remained mostly constant.

Initial Calibration Results: March 08, 2016 and March 15, 2016 against D116:

Initial lamp tests showed that the instrument wasn't able to undergo an initial intercomparison without some maintenance. The Mercury lamp tests were unstable, the PMT high voltage attenuator was inoperable and both the symmetry and PMT placement tests indicated significant alignment issues.

During an inspection of the optics the cobalt filter was found to be significantly marred by a white substance believed to be mold. We assumed that this was the reason for its instability and poor lamp tests. However, replacing the filter only shifted the standard lamp tests and had virtually no effect on mercury lamp tests.

Later it was determined that the poor mercury tests were due to a lack of high voltage attenuation to the PMT. When the mercury lamp was attenuated with a laboratory wipe, the results matched the Q-table quite well.

The original cobalt filter was placed back into the instrument for an initial intercomparison, but this did not return standard lamp tests to their original values.

Evaluation of the standard lamp tests performed prior to replacing the cobalt filter showed approximately 3% difference from the standard instrument before any Adjustments based on the results of Standard Lamp tests included.

Due to the poor state of the instrument, it was necessary to perform maintenance on instrument D090 prior to its participation in an initial inter-comparison. Some of that maintenance imparted changes to its calibration. It's impossible to state what those changes were with any certainty.

However an initial intercomparison showed:

d_Na: -0.50 d_Nc: +1.03 d_Nd: -1.08 d_Nad: +0.58

Which would impart an average error of 0.61% at mu=1.3 to 2.5 when TCO = 400 DU.

Work Performed:

- Symmetry test
- PMT position test
- Cobalt filter was replaced
- Q2 friction washer was replaced with a slightly thicker one and Q2 lever was adjusted
- Both Q1 and Q2 were reset to 84 degrees
- The 1970's power supplies were replaced with versions used in the automated Dobson. The rotary selector switch controlling PMT gain was replaced and the resistance of the lowest two steps was increased. The 5 mega ohm attenuator was also found to be faulty and replaced, and a single three mega ohm resistor was added to allow use of the mercury lamp without other means of attenuation –use of a Kim wipe.
- Both shutter rods were replaced and the shutter was adjusted
- M2 was adjusted
- Two lamp tests prior to and after optical cleaning
- Optical cleaning
- The head of the sun director was replaced
- Desiccant drying system was replaced
- Galvanometer was replaced
- Add standard lamp 090Q7
- New standard lamp values were assigned to 090Q2, 090Q5, and 090Q6

Second intercomparison:

Second intercomparison was attempted on March 17th. However, the PMT voltage attenuation circuit lacked sufficient resistance and most D measurements were erroneous.

Final intercomparison:

A new G-table was established from a two lamp test and corrections applied from IC performed on March 22nd.

d_Na: -26.62 d_Nc: -24.73 d_Nd:- 23.30

The results showed an average **-0.26% TCO difference** from the standard at **370 DU from mu = 1.24 to 2.5**

Comments:

The accuracy of measurements drops off precipitately at mu greater than 2.5. This is likely due to deterioration of M1. There was insufficient time and sun to address this issue during the IC.

Although electric power supply cable for the standard lamp showed large voltage depression, normal voltage of 24V was supplied to the lamp and the results of standard lamp tests were unaffected.

Recommendations:

- Intercomparisons should be performed more often. At least once every five years.
- We were unable to calibrate the instruments ADDSGQP measurements beyond mu = 2.5 in the allotted time. It's recommended that observations beyond this should not be made until this problem is resolved. However, due to the low latitude of Bangkok this shouldn't infringe upon the observation schedule currently in use.
- Review mercury lamp test to estimate when the PMT adjuster failed and scrutinize data for any impacts it might have had.
- The deteriorated cobalt filter was likely caused by high humidity. Exchange desiccant and air filters often and frequently check that the pump is working properly.
- If possible, add a knob to the 5 mega ohm potentiometer to improve control of the PMT gain.
- Clean the ground quartz plate monthly.
- Review past data using the RN table made prior to instrument cleaning and repairs and consider applying correction to data from the previous period.
- Begin using new R to N table.
- M1 should be replaced during the next IC.
- Changes in the instrument's behavior, such as loss of PMT control should be noted in a log to help address when failures occur.

Instrument: D100

Station: Quetta, Pakistan

Report on re-calibration and maintenance performed March 2016

Original Calibration Data:

N-tables (March, 2006) from intercomparison with D116 in Tsukuba Japan.
Standard lamp values for 100Q1, 100Q2, 100Q3, 100Q4 and 100Q5.

History:

D100 is routinely operated at the Quetta station using calibration constants from DIC-T 2006.

Mercury and standard lamp tests are sparse making overall assessment of past data very difficult.

The optics of this instrument were extremely dusty.

Initial Calibration Results: March 15, 2016 against D116:

d_Na: -0.62 d_Nc: +0.21 d_Nd: -2.73 d_Nad: +2.12

The d_Nad values implies an average **error of 2.22%** mu=1.3 to 2.5, Total Ozone = 400 Dobson units.

Work Performed:

- Thorough cleaning of optics
- Symmetry test
- PMT position test
- Two lamp tests prior to and after optical cleaning
- Optical cleaning
- Repair and ultimate replacement of standard lamp power supply and standard lamp holder
- Sun director prism adjuster repaired
- Galvanometer cable was replaced
- New standard lamp values were assigned to 100Q1, 100Q2, 100Q3, 100Q4 and 100Q5

Final intercomparison:

A new G-table was established from a two lamp test and corrections applied from IC performed on March 17th.

d_Na: -13.66 d_Nc: -12.42 d_Nd: -20.12

The results showed an average **-0.34% TCO difference** from the standard at **320 DU from mu = 1.25 to 2.5**

Comments:

This instrument exhibits a poor symmetry test, but the effects were not seen during the intercomparison.
Instrument operates well over a large mu range.

Recommendations:

- Perform and document mercury and standard lamp tests at least monthly.
- Try to keep the instrument clean.
  -Buy a vacuum cleaner for the floors and surfaces of the observatory.
  -Cover the instrument with a tarp or sheet when not in use and use.
  -Minimize the time the instrument spend out door.
  -Run the desiccant pump twenty-four hours a day.
- Wait for standard and mercury lamps to warm before performing tests.
- Clean the ground quartz plate monthly.
- Begin using new R to N table.
- With the absence of standard lamp tests past data should be reevaluated using the R to N table establish before optical cleaning.
- When making measurements a one degree movement of the R-dial should elicit a +/- 5 μ ampere response
- Intercomparisons should be performed more often. At least once every five years.
- Don't strongly tighten nuts on the stud bolts on the cover so that the light path in the instrument doesn't change due to deformation of the cover lid and packing.
- Follow standard operational procedures of Dobson instruments written in GAW report No. 183 to ensure continuous observation data quality at the observatory.